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Variations in Stomatal Traits of 14 Bornean Tree Species Growing on Soils with Different Moisture Contents in Lambir Hills National Park

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VARIATIONS IN STOMATAL TRAITS OF 14 BORNEAN TREE SPECIES GROWING ON SOILS WITH DIFFERENT MOISTURE CONTENTS IN LAMBIR HILLS NATIONAL PARK

by

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Abstract

The goal of this study was to look at variations in stomatal traits of tree species on soils with different moisture contents and fertility at Lambir Hills National Park. Stomates are important structures on the surface of leaves that mediate conduction of moisture and gasses in and out of the leaf. If stomatal traits are important for regulation, then there should be variation in stomatal traits in regards to their soil specialization. The 14 Bornean tree species sampled included 6 sandy loam specialists, 6 clay specialists and 2 generalists found growing with equal distributions on both sandy loam and clay. Confocal microscopy was used to capture images of the stomates. Measurements included inner pore width, inner pore length, and outer pore length along with density counts. These measurements were then used to determine the stomatal index. These Bornean tree species did not always respond consistently to variation in soil moisture with similar shifts in stomatal traits. There was also little phenotypic plasticity in stomatal traits with respect to soil type. The results of this study may lead to the idea that stomates may not be the only factor that is important for water regulation of these Bornean tree species and spark further investigation into other mechanisms of water conservation that help determine the relative importance of the stomatal index.

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Introduction

To understand the distribution and occurrence of plant species in different habitats, it is important to relate the structure and function of species to their environments (Fitter 1987, pg. 3). Habitats vary in environmental factors that are essential for plant success (Chapin 2002, pg. 12). These factors include light, nutrients and water. The availability of these resources in a habitat will determine which species are able to be successful.

The chance of finding a plant species in a particular habitat depends on at least two factors; the ability of the seed to colonize in its new habitat and its ability to survive to adulthood in that habitat. The survival of the species in its new habitat depends on interaction between the attributes of the species and environmental factors in the new habitat (Schupp *et al.* 1989). If individuals of a plant species do not have the necessary adaptations required to survive long enough to reproduce in a particular habitat, the species may not be able to establish a population there. This is a demographic process known as ecological sorting, the differential success of a plant species in different environments due to the species functional characteristics (Ackerly 2003).

By examining variations between species in their functional and structural traits, it is possible to identify potential factors which are important in determining the distribution of a plant species among different habitats. Ecological sorting results in variation in plant species composition among habitats by removing species that may have colonized in the habitat, but are not suited to the conditions of that environment (Ackerly 2003).

In any habitat, there are many environmental factors that are constantly changing. These include the amounts of water or nutrients available to the plant. Plants have responded to selection produced by the environment and developed adaptations to these environmental factors. Leaves are organs of plants that mediate photosynthesis, carbon acquisition, and water status. Stomates (Figure 1), important structures found on the epidermis of leaves, help accomplish these tasks (Martin 1983, pg. 1). The stomatal pore opening is surrounded by guard cells that cause the opening and closing of the pore due to fluctuations in water status and light. This opening and closing of the stomates allows for regulation and conduction of moisture and gasses in and out of the leaf (Dickison 2000, pg. 72). The success of a tree species in its environment depends on its ability to manipulate its responses and find a balance between photosynthetic uptake of CO_2 and water conservation (Fitter 1987, pg.143).

Stomates are primarily located on the lower surface of the leaf; however, some plants have stomates on their upper surface (Zeiger 1987, pg 60). Most plants have a greater number of stomates on their abaxial surface (Kirkham 2005, pg. 381). It is advantageous for a plant to have the majority of its stomates on the lower surface of the leaf since this side is generally more protected from excess sunlight. The total area of a leaf allocated to stomatal pores can vary among plant species by having a large number of small stomates or a small number of large stomates. The growth rate of a plant is directly related to the photosynthetic rate of a plant (Fitter 1987, pg. 6). This is correlated with stomatal conductance, the rate at which CO2 enters the leaf. For these reasons, stomates mediate plant responses to variations in soil moisture and sunlight, which are important determinates of plant growth and survival in different environments.

Within a forest dynamics plot in Lambir Hills National Park (Figure 2), an environmental gradient is present with variations in above- and below-ground resources that are important to trees. Two types of soil comprise the extremes of this gradient:

sandy loam and clay, which vary in nutrient and water availability as well as light. The clay soils of this gradient have high moisture content and a relatively greater availability of nutrients compared to the sandy loam (Davies *et al.* 2005, SE Russo unpublished data). The sandy loam soil is well drained and nutrient depleted. This resource gradient influences the distribution of tree species and seemingly because tree species are sorted along it (Davies *et al.* 2005).

Species adapted to living in moist soils often have a high stomatal conductance rate (flux of water vapor or CO_2 (Chapin 2002, pg. 101)), often associated with a high density of stomates or large stomates. Plants adapted to living in drier soils often have adaptations to prevent water loss such as lower densities of smaller stomates. The stomatal index is calculated by multiplying the density of the stomates by the length and width of the guard cells and is strongly correlated with stomatal conductance (Sack *et al.* 2003). Since stomatal pore size itself is difficult to measure accurately, the length and width of the guard cells are used as accepted estimates of pore size. Individuals living on nutrient-rich soils are generally faster growing; these species need high levels of conductance to support high rates of photosynthesis needed for their fast growth. Individuals living on nutrient-depleted soils have growth rates adapted to the lack of nutrients in their soil type; their growth rates are adapted to tolerate soils with lower nutrient availability (Grime 1977).

The goal of this study was to look at variations in stomatal traits of tree species on soils with different moisture contents and fertility at Lambir Hills National Park. If stomatal traits are important for regulating a tree's water status, then tree species growing on the clay end of the gradient will have a higher density of larger stomates, and species growing on the sandy loam will have lower densities of smaller stomates. I tested this hypothesis using data on stomatal density and size for 14 Bornean tree species that are congeneric species pairs in which one is a habitat specialist of sandy loam and the other is a specialist of clay and two species that are habitat generalists and are equally abundant on both clay and sandy loam. I further predicted that variation in stomatal traits within generalist species between soil types would be similar to the variation between specialists. Therefore, I expect to find that the leaves of species or individuals sampled from the clay end of the soil gradient will have high densities of large stomates and a high stomatal pore index.